United States Department of Agriculture
Soil Conservation Service
P.O. Box 2890
Washington, D.C.
20013

TR-77B

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TECHNICAL RELEASE NO. 77, AMENDMENT 2
210-VI

SUBJECT: ENG - TECHNICAL RELEASE NO. 77, DESIGN AND INSTALLATION OF FLEXIBLE CONDUITS -- APPENDIX G

Purpose. To distribute Appendix G, Technical Release No. 77 (TR-77B) and the associated microcomputer program.

Effective Date. Effective upon receipt.

Technical Release No. 77 (TR-77) may be used to design buried or nonburied plastic pipe. TR-77B documents and provides user instructions for the computer program developed to analyze plastic pipe in conformance with the procedures contained in TR-77. Morris N. Lobrecht, Design Engineer, at the South National Technical Center (SNTC), developed this program, and it was tested at the National Software Testing Laboratory, SNTC.

Filing Instructions. Insert Appendix G between pages 90 and 91 of TR-77.

Distribution. Distribution of Appendix G is as indicated by the TR-77 distribution list. Under separate cover, a diskette containing the program will be distributed to the States and NTC's. Additional copies of the program may be duplicated as needed. Additional copies of Appendix G may be obtained by ordering TR-77B from the Consolidated Forms and Distribution Center, 3222 Hubbard Road, Landover, Maryland 20785.

Edgar H. Nelson
for

ROBERT R. SHAW
Deputy Chief for Technology

Enclosure

Appendix G — Computer Program

Preface

The procedure in Technical Release 77 (TR–77) may be used to design buried or nonburied plastic pipe. This appendix contains a user friendly menu driven computer program using the TR-77 procedure to aid as a design tool.

This appendix was prepared by Morris N. Lobrecht, Design Engineer, Design Section, South National Technical Center, Fort Worth, Texas.

Contents

Symbols

The symbols used below are used in the computer program.

ARB a computed strain index for a given angle. When ARB is less than 1.0 the strength adequacy for tension strain is satisfied.

BPRM value used in computing PCR

CW reduction of earth load for buoyancy

DELTAI deflection that occurs during installation in percent

DELTAS average deflection due to soil pressure in percent

DELTAT total deflection in percent

DELTAW average deflection due to wheel loading in percent

DLF deflection lag factor

DR dimension ratio

E modulus of elasticity of the pipe material in psi

EBIU factored ring bending strain that occurs during installation

EBSU factored ring bending strain due to soil loads

EBU sum of factored ring bending strains

EBWU factored ring bending strain due to wheel loads

EC strength in creep

ECGU factored ring compression strain due to groundwater

ECSU maximum factored ring compression strain due to earth loads

ECU initial reduced ultimate strain in creep

ECVU factored ring compression strain due to vacuum

EEWU maximum factored ring compression strain due to groundwater

ECWU maximum factored ring compression strain due to wheel load

EPCSU minimum factored ring compression strain due to soil load

EPCWU minimum factored ring compression strain due to the wheel loading

EPRM modulus of soil reaction of embedment material,in psi

ER strength in relaxation

ERU initial reduced ultimate strain in relaxation

ETU maximum ring tensile strain due to internal pressure in the pipe

GAMA unit weight of soil in pcf

H height of soil above the top of the pipe in feet

HW height of groundwater above the top of the pipe in feet

IF symbol in screen output for input factor

JUNK value used to compute BPRM

KB bedding constant

MF moment factor

OD average outside diameter of pipe in inches

P live load or wheel load at surface, pounds

PB	pressure on bottom region, earth load reduced for buoyancy in psi
PBU	ultimate factored presure on the pipe bottom in psi
PCR	critical buckling pressure of the pipe, psi
PF	internal pressure, psi
PFU	ultimate factored internal pressure, psi
PG	groundwater pressure
PGU	ultimate factored groundwater pressure, psi
PPCR	critical buckling pressure on the pipe under hydrostatic loading
PPF	strain concentration factor at the perforations
PPSU	mimimun factored pressure due to the soil load in psi
PPWU	minimum factored pressure due to the wheel load in psi
PS	soil pressure, psi
PSIO	pipe stiffness after 10 years, psi
PSO	initial pipe stiffness, psi
PSU	ultimate factored pressure on pipe from soil load, psi
PV	vacuum pressure in psi
PVU	ultimate factored vacuum pressure, psi
PW	pressure due to wheel loading excluding load factors, psi
PWH	pressure due to wheel loading including load factors, psi
PWU	ultimate factored pressure due to wheel loading in psi
RA	compression strain index
RB	tension strain index
RC	tension index
RD	buckling index
RE	hydrostatic bucking index
SDR	standard dimension ratio as defined in ASTM F 412
T	minimum wall thickness, in
TIFF	impact factor

Introduction

This appendix uses the procedure in Technical Release 77 (TR-77) in a menu driven program to aid in the design of plastic pipe. The program was specifically written for buried smooth-walled PVC pipe but can be used for other types of pipe and for specific conditions of nonburied pipe. Other types (not PVC) of plastic pipe must be smooth-walled to use the program.

Purpose

The purpose of this appendix is to document the computer program that uses TR-77 procedures to aid in the design of plastic pipe for deflection and strain. The hydraulic design is not considered in this program.

Computer Program

The computer program, written in GWBASIC for use with an AT&T PC 6300, determines the deflection and strain of the pipe from the loading conditions supplied by the user.

The computer program was specifically written as a design tool for buried PVC plastic pipe. It can be used to design other types of plastic pipe and for some special cases of nonburied plastic pipe. These special cases involve loads from internal pressure, vacuum, and external water.

Except for nonburied pipe the program uses the procedures outlined or documented in TR-77. For nonburied pipe the program uses a modification of the procedure that was developed by Euler and incorporates a safety factor in the pipe design. (See the flow chart.)

The computer program contains the physical information currently available for PVC pipe that is specified by SCS in the PIPEDATA file. When the program is run this information is automatically loaded into the program.

The program requires a stand alone IBM compatible PC using MS-DOS to run the program. The program disk contains an executable program PVCDSN.EXE and a PIPE DATA file. The program can be run from the disk drive or it can be copied to the hard disk, but the PIPEDATA file must be on the same drive as the program PVCDSN.EXE to work.

To run the program select the disk drive on which the program resides, type PVCDSN, then press enter to start the program.

Example 1
Basic Information

Basic project information is entered as shown in Example 1

```
ENTER YOUR NAME ============> ? MORRIS N LOBRECHT
ENTER THE PROJECT NAME ======> ? TEST3
ENTER THE STATE  ============> ? SOUTH NATIONAL TECHNICAL CENTER
```

Example 2
Main Menu
Select Type of Pipe

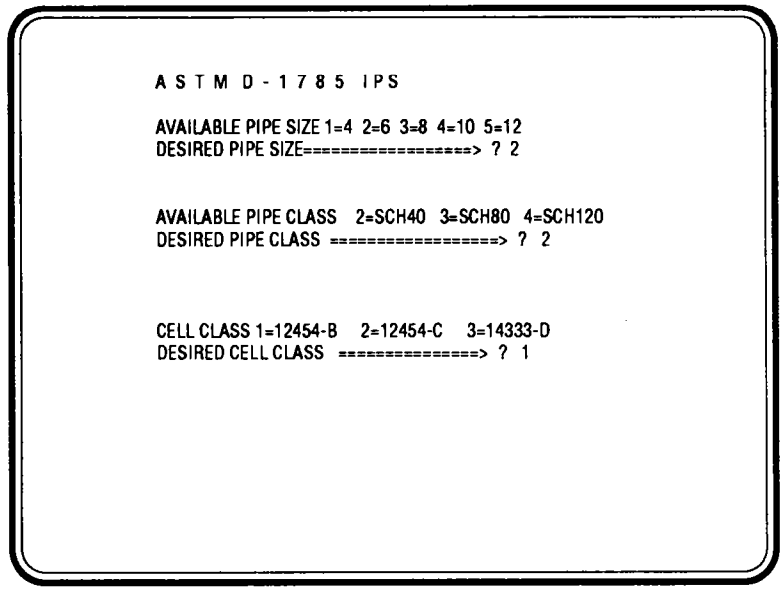
The MAIN MENU of the program requires the user to select the type of pipe to be used for design from the option screen, such as AWWA C-900 or ASTM D2241 IPS.

```
SOIL CONSERVATION SERVICE                                    S N T C

BURIED OR NONBURIED PVC PLASTIC PIPE - DESIGN OPTIONS -

SELECT OPTION:                                    LAST REVISED 1/91

                    A - AWWA C-900
                    B - ASTM D2241 IPS
                    C - SCHEDULE ASTM D1785 IPS
                    D - PIP HIGH HEAD
                    E - PIP LOW HEAD
                    F - NONPRESSURE ASTM D3033
                    G - NONPRESSURE ASTM D3034
                    H - NONPRESSURE ASTM F679
                    I - NONPRESSURE ASTM F789
                    J - NONPRESSURE ASTM F758
                    K - OTHER
                    L - RETURN TO CHANGE INPUT DATA
                    Q - QUIT (RETURN TO DOS)

                SELECT AN OPTION FROM ABOVE=====> ? C
```

Example 3
Select the Required Pipe Data

When the user selects the type and size of pipe to be used for design, the program labels the type of pipe, pipe diameter, cell class, outside diameter of the pipe, wall thickness of the pipe, and Young's modulus, E, for the pipe.

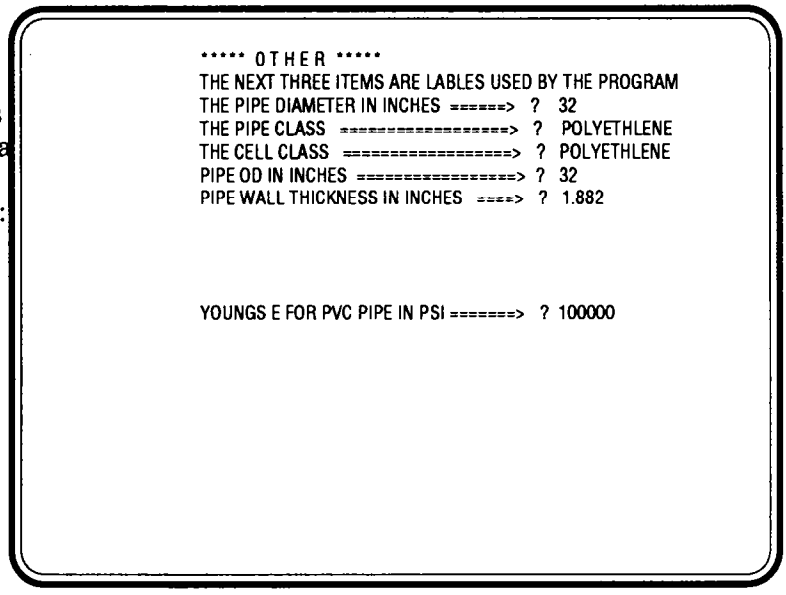
At this point the program displays information on pipe size. The user is required to enter the pipe size for the design. After the size is selected the screen displays information on the pipe classes available for this type of pipe and the user enters the class to be used in the design. Then the screen displays cell class information that is available for this type of pipe and the user is required to select the cell class to be used in the design.



Example 4
Other Pipes

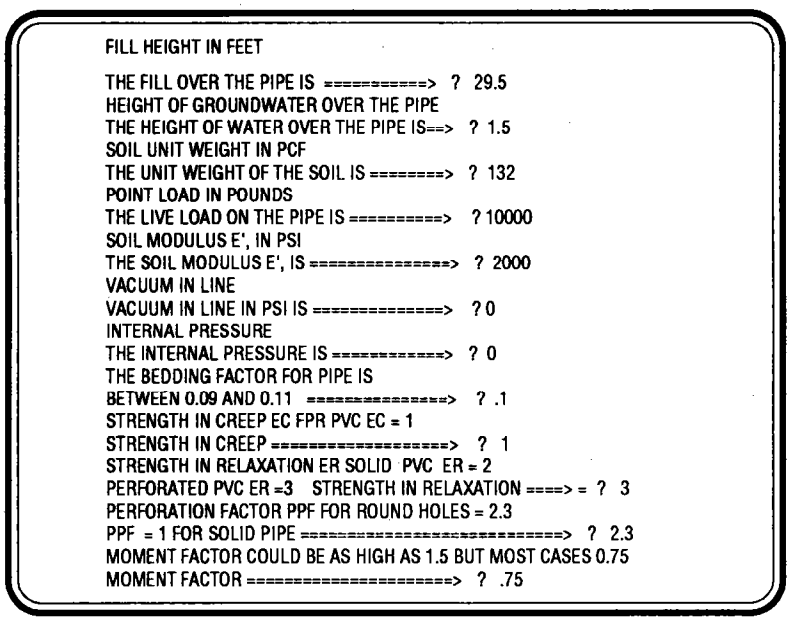
If the design is for a plastic pipe type other than PVC the OTHER option is selected. When this is done the user is required to supply the following from a standard specification such as ASTM, ANSI, Federal Specs, or other sources:

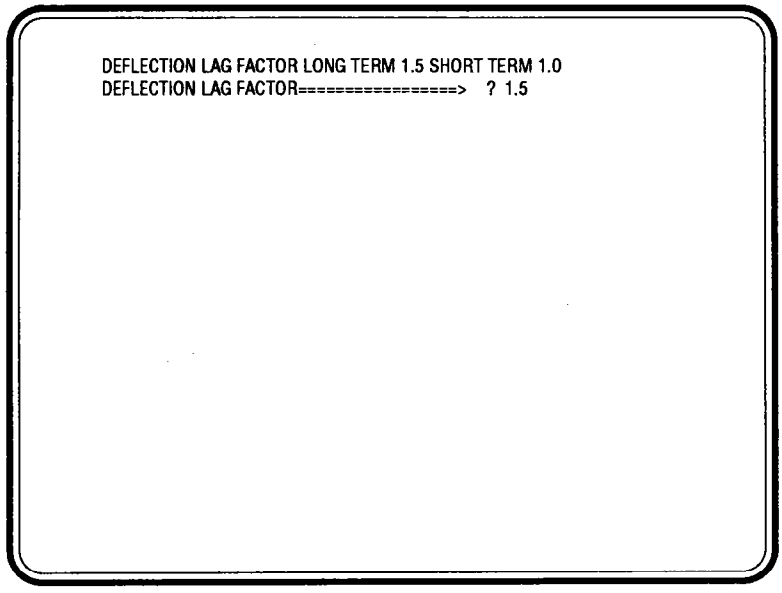
1. Pipe Diameter
2. Pipe Name of Class
3. Pipe Cell Class
4. Pipe Outside Diameter in inches
5. Pipe Wall Thickness in inches
6. Young's E for the Pipe in psi



Example 5
Loadings

At this point the program requires data for loads, soils, and specific pipe data from the user. (See Appendix, Flow Chart — Input Data) There is also information in TR-77 to provide guidance on this information or data required by the program. The following information is required.





1. **Loading from soil** in fill height over the pipe in feet. If H = 0 the pipe will be designed as a nonburied pipe.

2. **Loading from water** in water height over the pipe in feet. For buried pipe the height of water cannot exceed the height of fill.

3. **The unit weight** of the soil is required to compute soil loads. Only one unit weight is allowed for computations. The program will consider buoyant soil weights but it is up to the user to average the unit weights of the soil if more than one density of fill is used over the pipe. *In most cases the moist or saturated unit weight of the soil is adequate.*

4. **Live load** (wheel or point load) at the ground surface in pounds. No live loads are allowed on nonburied pipe.

5. **Modulus of Soil Reaction E'** in psi for the fill within 2D of the pipe. See TR-77, p. 23, Table 4, for guidance.

6. **Vacuum** —for pressure flow conditions the maximum vacuum that could be expected in the line in psi.

7. **Internal pressure** — for pressure flow the maximum expected pressure in psi.

8. **Bedding factor** for pipe — See TR-77, p. 21 for guidance.

9. **Strength in creep factor** — See TR-77, p. 32 for guidance.

10. **Strength in relaxation factor** See TR-77, p. 32 for guidance.

11. **Perforation factor** 1 for solid pipe. See TR-77, p. 26 for guidance regarding perforation factors.

12. **Moment factor** See TR-77, p. 26 for guidance.

13. **Deflection lag factor** See TR-77, p. 21 for guidance.

Example 6
Input Data and Changes to Input Data

At this point the computer program displays the input data and asks if the user wants to change anything. This data is available and any or all data can be changed for additional runs until the user returns to the MAIN MENU. All input data is lost if the MAIN MENU is used to make a pipe selection.

```
INPUT DATA
ASTM D-1785  IPS       SCH40      12454-B                              6

                    A - FILL HEIGHT ============== 29.5
                    B - PIPE OD ================== 6.625
                    C - SOIL UNIT WEIGHT ========= 132
                    D - POINT LOAD =============== 10000
                    E - SOIL MODULUS E', ========== 2000
                    F - WALL THICKNESS ============ .28
                    — YOUNGS E FOR PVC PIPE ==== 400000
                    G - INTERNAL PRESSURE ======= 0
                    H - BEDDING FACTOR FOR PIPE ==.1
                    I - STRENGTH IN CREEP EC ====== 1
                    J = STRENGTH IN RELAXATION ER = 3
                    K - WATER HEIGHT ============ 1.5
                    L - PERFORATION FACTOR ====== 2.3
                    M - VACUUM IN LINE ============ 0
                    N - MOMENT FACTOR ========== .75
                    O - DEFLECTION LAG FACTOR ====1.5
                    P - PIPE PARAMETERS ========= ASTM  D-1785  IPS
DO YOU WANT TO CHANGE ANY OF THE INPUT DATA (Y/N)? Y
```

```
                    ********** CHANGE INPUT DATA **********
ASTM D-1785  IPS       SCH40      12454-B                              6

                    A - FILL HEIGHT ============== 29.5
                    B - PIPE OD ================== 6.625
                    C - SOIL UNIT WEIGHT ========= 132
                    D - POINT LOAD =============== 10000
                    E - SOIL MODULUS E', ========== 2000
                    F - WALL THICKNESS ============ .28
                    — YOUNGS E FOR PVC PIPE ==== 400000
                    G - INTERNAL PRESSURE ======= 0
                    H - BEDDING FACTOR FOR PIPE ==.1
                    I - STRENGTH IN CREEP EC ====== 1
                    J = STRENGTH IN RELAXATION ER = 3
                    K - WATER HEIGHT ============ 1.5
                    L - PERFORATION FACTOR ====== 2.3
                    M - VACUUM IN LINE ============ 0
                    N - MOMENT FACTOR ========== .75
                    O - DEFLECTION LAG FACTOR ====1.5
                    P - PIPE PARAMETERS ========= ASTM  D-1785  IPS
                    R - RUN REVISED INPUT DATA
                    OPTION?
```

Example 7
Input Data and Changes to Input Data

Select the necessary menu item.

```
**************************
        MENU
**************************

1. MAKE CHANGE(S) IN INPUT
2. PRINT FINAL RESULTS
3. CREATE A PRINT FILE  (for use on remote printer)
4. RETURN TO MAIN MENU
5. MAKE STRAIN COMPS BY DEGREES OUTPUT TO SCREEN
6. MAKE STRAIN COMPS BY DEGREES OUTPUT TO PRINTER


INPUT THE NUMBER NEXT TO THE APPROPRIATE RESPONSE ====>? 1
```

Example 8
Input Data and Changes to Input Data

To change the pipe, select either P—Pipe Parameters, B–Pipe OD, or F–Wall thickness.

```
********** CHANGE INPUT DATA **********
  ASTM D-1785   IPS    SCH40   12454-B    6
A - FILL HEIGTH ================ 29.5
B - PIPE OD ==================== 6.625
C - SOIL UNIT WEIGHT ========== 132
D - POINT LOAD ================ 10000
E - SOIL MODULUS E, =========== 2000
F - WALL THICKNESS ============ .28
—YOUNGS E FOR PVC PIPE ======= 400000
G - INTERNAL PRESSURE ======== 0
H - BEDDING FACTOR FOR PIPE === .1
I - STRENGTH IN CREEP EC ======= 1
J = STRENGTH IN RELAXATION ER = 3
K - WATER HEIGHT =============== 1.5
L - PERFORATION FACTOR ======== 2.3
M - VACUUM IN LINE ============ 0
N - MOMENT FACTOR ============= .75
O - DEFLECTION LAG FACTOR ===== 1.5
P - PIPE PARAMETERS ==========  ASTM D-1785 IPS
R - RUN REVISED INPUT DATA
OPTION? P
```

Example 9
Input Data and Changes to Input Data

This will display a pipe option menu which will allow the user to change pipes without changing the rest of the input data for other design runs.

```
A - AWWA C-900
B - ASTM D2241 IPS
C - SCHEDULE ASTM D1785 IPS
D - PIP HIGH HEAD
E - PIP LOW HEAD
F - NONPRESSURE ASTM D3033
G - NONPRESSURE ASTM D3034
H - NONPRESSURE ASTM F679
I - NONPRESSURE ASTM F789
J - NONPRESSURE ASTM F758
K - OTHER
L - RETURN TO CHANGE INPUT DATA
Q - QUIT (RETURN TO DOS)
SELECT AN OPTION FROM ABOVE? B
```

When changing pipes the program requires that the user selects the type, size, class, and the cell class of the pipe for each change.

```
A S T M  D - 2 2 4 1  I P S

AVAILABLE PIPE SIZE 1=4 2=6 3=8 4=10 5=12 6=14 7=16 8=18 9=20 10=24 11=30 12=3
DESIRED PIPE SIZE ==================> ? 2


PIPE CLASS 2=SDR64 3=SDR41 4=SDR32.5 5=SDR26 6=SDR21 7=SDR17 8=SDR13.5
DESIRED CLASS ====================> ? 7


CELL CLASS 1=12454-B 2=12454-C 3=14333-D
DESIRED CELL CLASS ================> ? 1
```

If the user does not want to make any changes in input data enter N <cr> and the program asks for installation deflection (See example 6 where the user wanted to change input data). If changes have been made in the input data the user must enter R <cr> to resume execution of the program.

Note: The program is written to accept upper and lower case keyboard responses.

```
********** CHANGE INPUT DATA **********
  ASTM  D-2241  IPS   SDR17  12454-B   6

A - FILL HEIGHT ============== .29.5
B - PIPE OD ================== 6.625
C - SOIL UNIT WEIGHT ========== 132
D - POINT LOAD =============== 10000
E - SOIL MODULUS E' ========== 2000
F - WALL THICKNESS =========== .39
YOUNGS E FOR PVC PIPE ======= 400000
G - INTERNAL PRESSURE ======= 0
H - BEDDING FACTOR FOR PIPE == .1
I - STRENGTH IN CREEP EC ====== 1
J = STRENGTH IN RELAXATION ER = 3
K - WATER HEIGHT ============= 1.5
L - PERFORATION FACTOR ======= 2.3
M - VACUUM IN LINE =========== 0
N - MOMENT FACTOR ============ .75
O - DEFLECTION LAG FACTOR ==== 1.5
P - PIPE PARAMETERS ========== ASTM D-2241 IPS
R - RUN REVISED INPUT DATA
OPTION?
```

```
********** CHANGE INPUT DATA **********
  ASTM  D-2241  IPS   SDR17   12454-B   6

A - FILL HEIGHT ================ 29.5
B - PIPE OD ================== 6.625
C - SOIL UNIT WEIGHT ========== 132
D - POINT LOAD ================ 10000
E - SOIL MODULUS E, ========== 2000
F - WALL THICKNESS ============ .39
YOUNGS E FOR PVC PIPE ======== 400000
G - INTERNAL PRESSURE ======== 0
H - BEDDING FACTOR FOR PIPE === .1
I - STRENGTH IN CREEP EC ====== 1
J = STRENGTH IN RELAXATION ER = 3
K - WATER HEIGHT ============= 1.5
L - PERFORATION FACTOR ======= 2.3
M - VACUUM IN LINE ============ 0
N - MOMENT FACTOR ============ .75
O - DEFLECTION LAG FACTOR ===== 1.5
P - PIPE PARAMETERS ========== ASTM D-2241 IPS
R - RUN REVISED INPUT DATA

OPTION? R
```

Example 10 Installation Deflection

When H = 0 (nonburied pipe), the user must supply the installation deflection. When the pipe is buried, the program provides a table based upon the compaction of the material around the pipe (within 2D) and the pipe stiffness to guide the user in selection of the installation deflection.

The program then computes the deflection and the strain index. (See Appendix for equations used for the computations)

```
IF PIPE STIFFNESS < 34 RESULTS MAY NOT APPLY
PIPE STIFFNESS =  437.5743

INSTALLATION DEFLECTION (%)

                                    PERCENT DENSITY
PIPE STIFFNESS  |  <85  |  85-95  |  >95
<40             |  6+   |  4      |  3
40-100          |  4+   |  3      |  2
>100            |  2+   |  2      |  1

INPUT FROM TABLE % DEFLECTION ==>? 2
```

Example 11 Screen Output

The computed information is then displayed on the screen.

For PVC plastic pipe

If the total long-term or short-term deflections are greater than acceptable values (generally 5 % and 3 %, respectively) then the pipe must be redesigned.

If the deflections meet minimum requirements, the strain indices, compression strain index (RA), tension strain index (RB), tension index (RC), Buckling index (RD), and Hydrostatic buckling index (RE) need to be checked. If any are greater than 1.0 then the pipe must be redesigned. In the case of perforated pipe, when only RB exceeds 1.0, the program contains a procedure that may allow the user to employ the selected pipe that has alternate hole locations for the perforations.

```
      *****OUT PUT*****
BURIED  ASTM D-2241 IPS SDR17 12454-B 6
DR OR SDR ==============      16.98718
PSO PSIO ================  437.574   218.787
SOIL LOADS PS PSU PPSU ====  27.042   40.563   21.633
WHEEL LOADS PW PWU PPWU =     0.038    0.069    0.031
CW PB PBU PWH IF ==========   0.983   26.583   39.875   0.038   1.001
PG PGU PV PVU ============    0.645    0.645    0.000   0.000
PF PFU ==================     0.000    0.000
DELTAS ==================     2.167
DELTAW ==================     0.003
DELTAI ==================     2.000        %
DELTAT                        4.170        %
EBSU EBWU EBIU EBU ========  0.7624   0.0013   0.4016   1.1652
ETU EEWU EPCWU ===========  0.00000  0.00001  0.00006
ECSU EPCSU ECWU ECVU ======  0.08613  0.04594  0.00015  0.00000
=============================================================
RA RF RC RB                  0.5934 1.0000  0.4280  1.0592
PCR =====================    243.22
RD PPCR RE ==============  0.1669 %123.0678  0.0052
JUNK BPRM ============== 53.4340    0.8981
IF PSO < 34 RESULTS MAY NOT APPLY
PRESS ANY KEY TO CONTINUE
```

For other pipe

The deflection limits or criteria will be established by the user from other sources.

At this point it is helpful to the user to note the SDR or DR shown on the screen. This will aid the user if another pipe must be selected for design.

Example 12 Submenu

After the output to the screen is noted, pressing any key will take the user to a submenu that will allow changing input data, printing results to a slave printer, making a print file that can be printed on a remote printer, or returning to the main menu Note: If you return to the MAIN MENU option L will allow you to make changes to the existing input data. If a pipe option is selected from the MAIN MENU then all of the required input data must be re-entered.

```
**********
   MENU
**********
1. MAKE CHANGE(S) IN INPUT
2. PRINT FINAL RESULTS
3. CREATE A PRINT FILE (for use on remote printer)
4. RETURN TO MAIN MENU
5. MAKE STRAIN COMPS BY DEGREES OUTPUT TO SCREEN
6. MAKE STRAIN COMPS BY DEGREES OUTPUT TO PRINTER

INPUT THE NUMBER NEXT TO THE APPROPRIATE RESPONSE ——>? 2
```

Example 13 Printed Output

```
PVC PIPE DESIGN

          BURIED          LONG TERM

        S C S - - SNTC   LAST REVISED JANUARY 1991

STATE      SOUTH NATIONAL TECHNICAL CENTER      PROJECT      TEST3
BY MORRIS N LOBRECHT   01-03-1990          CHECKED BY_____
SUBJECT_____
_____SHEET____OF_____

INPUT DATA

ASTM D-2241  IPS   SDR17   12454-B
6 INCH DIAMETER   SOLID PIPE

FILL HEIGHT IN FEET ========================   29.5
PIPE OD IN INCHES ==========================   6.625
SOIL UNIT WEIGHT IN PCF ====================   132
WHEEL LOAD IN POUNDS =======================   10000
SOIL MODULUS E, IN PSI =====================   2000
PIPE WALL THICKNESS IN INCHES ==============   .39
YOUNGS E FOR PVC PIPE IN PSI ===============   400000
INTERNAL PRESSURE ==========================   0
BEDDING FACTOR =============================   .1
STRENGTH IN CREEP EC =======================   1
STRENGTH IN RELAXATION ER ==================   3
WATER HEIGHT IN FEET =======================   1.5
PERFORATION FACTOR =========================   2.3
VACUUM IN LINE =============================   0
MOMENT FACTOR ==============================   .75
DEFLECTION LAG FACTOR ======================   1.5

OUTPUT DATA

   ASTM D-2241  IPS  SDR17  12454-B  6

DR OR SDR ==================================   16.98718
PSO ========================================   437.574
IMPACT FACTOR FOR LIVE LOAD ================   1.001
SOIL DELTA =================================   2.167%
WHEEL DELTA ================================   0.003%
INSTALLATION DELTA =========================   2.000%
TOTAL DELTA ================================   4.170%
IF RA, RB, RC, RD, OR RE IS GREATER THAN 1 THEN REDESIGN
IF ONLY RB > 1 CAN USE STEP 5 OF MENU FOR HOLE LOCATIONS FOR RB
RA COMP. STRAIN INDEX ======================   0.5934
RB TENSION STRAIN INDEX ====================   1.0592
RC TENSION INDEX ===========================   0.4280
RD BUCKLING INDEX ==========================   0.1669
RE HYDRO. BUCKLING INDEX ===================   0.0052

IF PSSO < 34 RESULTS MAY NOT APPLY
```

Example 14
Alternate Locations for Perforations Which Satisfies RB

When strain computations are made for RB, the user can restrict the location of the holes in the pipe to get the strain index to 1.0 or below. This may allow the user to use the pipe selected if construction will allow alternate hole locations. The pipe design procedure in the main program allows the holes to be placed in any location or angle as long as the strain index for RB is 1.0 or less. When this index is greater than 1.0, the routine for alternative locations (angles) only prints the angles where the strain index of RB is 1.0 or less.

The angle in degrees (DEG) and the strain index (ARB) associated with this angle (DEG) are computed. Only ARB less than 1.0 are printed which indicate allowable values for the alternate location which is the angle DEG. The angle DEG is measured from the horizontal plane through the center of the pipe.

WARNING: The program prints exact limits for perforation locations with no tolerance for construction. It is up to the user to select a reasonable tolerance to assure that the holes will not be installed outside the limits established by the program. As a rule of thumb a minimum of plus or minus 15 degrees can be used for construction tolerance.

After the selected pipe has been designed and the results printed, the user must return to the main menu to exit (quit) the program.

```
**********
MENU
**********

1. MAKE CHANGE(S) IN INPUT
2. PRINT FINAL RESULTS
3. CREATE A PRINT FILE (for use on remote printer)
4. RETURN TO MAIN MENU
5. MAKE STRAIN COMPS BY DEGREES OUTPUT TO SCREEN
6. MAKE STRAIN COMPS BY DEGREES OUTPUT TO PRINTER

INPUT THE NUMBER NEXT TO THE APPROPRIATE RESPONSE ---->?6
```

THE VALUES OF ARB LESS THAN 1 DEFINES THE LIMITING ANGLE FOR HOLES

DEG	ARB
10.00000	0.99184
11.00000	0.97787
12.00000	0.96264
13.00000	0.94617
14.00000	0.92847
15.00000	0.90957
16.00000	0.88950
17.00000	0.86827
18.00000	0.84591
19.00000	0.82246
20.00000	0.79793
21.00000	0.77235
22.00000	0.74577
23.00000	0.71821
24.00000	0.68970
25.00000	0.66029
26.00000	0.63000
27.00000	0.59887
28.00000	0.56694
29.00000	0.53425
30.00000	0.50084
31.00000	0.46675
32.00000	0.43202
33.00000	0.39669
34.00000	0.36081
35.00000	0.32443
36.00000	0.28757
37.00000	0.25030
38.00000	0.21265
39.00000	0.17467
40.00000	0.13641
41.00000	0.09791
42.00000	0.05922
43.00000	0.02039

44.00000	-0.01853
45.00000	-0.05750
46.00000	-0.01853
47.00000	0.02039
48.00000	0.05922
49.00000	0.09791
50.00000	0.13641
51.00000	0.17467
52.00000	0.21265
53.00000	0.25030
54.00000	0.28757
55.00000	0.32443
56.00000	0.36081
57.00000	0.39669
58.00000	0.43202
59.00000	0.46675
60.00000	0.50084
61.00000	0.53425
62.00000	0.56694
63.00000	0.59887
64.00000	0.63000
65.00000	0.66029
66.00000	0.68970
67.00000	0.71821
68.00000	0.74577
69.00000	0.77235
70.00000	0.79793
71.00000	0.82246
72.00000	0.84591
73.00000	0.86827
74.00000	0.88950
75.00000	0.90957
76.00000	0.92847
77.00000	0.94617
78.00000	0.96264
79.00000	0.97787
80.00000	0.99184

Example 15
Quit

```
                 ************************
                          MENU
                 ************************

        1. MAKE CHANGE(S) IN INPUT
        2. PRINT FINAL RESULTS
        3. CREATE A PRINT FILE        (for 3B2 printer)
        4. RETURN TO MAIN MENU
        5. MAKE STRAIN COMPS BY DEGREES OUTPUT TO SCREEN
        6. MAKE STRAIN COMPS BY DEGREES OUTPUT TO PRINTER

INPUT THE NUMBER NEXT TO THE APPROPRIATE RESPONSE ====>? 4
```

```
      SOIL CONSERVATION SERVICE        S N T C

        BURIED OR NONBURIED PVC PLASTIC PIPE - DESIGN OPTIONS -

SELECT OPTION:                                   LAST REVISED 1/91

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o                  A - AWWA C-900                              o
o                  B - ASTM D2241 IPS                          o
o                  C - SCHEDULE ASTM D1785 IPS                 o
o                  D - PIP HIGH HEAD                           o
o                  E - PIP LOW HEAD                            o
o                  F - NONPRESSURE ASTM D3033                  o
o                  G - NONPRESSURE ASTM D3034                  o
o                  H - NONPRESSURE ASTM F679                   o
o                  I - NONPRESSURE ASTM F789                   o
o                  J - NONPRESSURE ASTM F758                   o
o                  K - OTHER                                   o
o                  L - RETURN TO CHANGE INPUT DATA             o
o                  Q - QUIT (RETURN TO DOS)                    o
àéééééééééééééééééééééééééééééééééééééééééééééééééééééééééééé¥
              SELECT AN OPTION FROM ABOVE=====>? Q
      DO YOU REALLY WANT TO QUIT  (Y/N)  ? ? Y
```

FLOW CHART

PVC PIPE DESIGN PROGRAM FOR DEFLECTION AND STRAIN

FOR A PC-6300 WITH A PRINTER
LOGIN
ALT F9
C>
A: <CR>
A: INSERT DISK INTO DRIVE "A"
A: PVCDSN <CR>

INPUT "PIPEDATA"
THE PROGRAM LOADS THE OUTSIDE DIAMETER AND WALL THICKNESS INTO THE DATA TABLE.

***** MAIN MENU *****

SELECT PIPE OPTION A→K

A - AWWA C-900
B - ASTM D2241 IPS
C - SCHEDULE ASTM D1785 IPS
D - PIP HIGH HEAD
E - PIP LOW HEAD
F - NONPRESSURE ASTM D3033
G - NONPRESSURE ASTM D3034
H - NONPRESSURE ASTM F679
I - NONPRESSURE ASTM F789
J - NONPRESSURE ASTM F758
K - OTHER
L - RETURN TO CHANGE IMPUT DATA
Q - QUIT (RETURN TO DOS)

PIPE SIZE 1→?
LABEL OUTPUT FOR PIPE SIZE
PIPE CLASS 2→?
LABEL OUTPUT FOR PIPE CLASS
CELL CLASS 1→?
LABEL OUTPUT FOR CELL CLASS

THE PROGRAM SELECTS AND LABELS
OUTSIDE DIAMETER OF THE PIPE IN INCHES--OD
WALL THICKNESS IN INCHES ----------T
YOUNG'S MODULUS FOR PVC PIPE IN PSI ----E

***** INPUT DATA *****

FILL HEIGHT OVER THE PIPE IN FEET ------ H [1]
WATER HEIGHT OVER THE PIPE IN FEET ----- HW
UNIT WEIGHT OF THE SOIL IN PCF --------- GAMA
WHEEL LOAD OR POINT LOAD AT GROUND SURFACE IN POUNDS ---------- P
SOIL MODULUS IN PSI ---------- EPRM
VACUUM IN LINE IN PSI ---------- PV
INTERNAL PRESSURE IN LINE IN PSI ------- PF
BEDDING FACTOR FOR PIPE ---------- KB
STRENGTH IN CREEP FACTOR ---------- EC
STRENGTH IN RELAXATION FACTOR ---------- ER
PEFORATION FACTOR ---------- PPF
MOMENT FACTOR ---------- MF
DEFLECTION LAG FACTOR ---------- DLF

DO YOU WANT TO CHANGE INPUT DATA Y/N ?
YES
NO

CHANGE INPUT DATA
A - P } MAKE CHANGE
R - RUN REVISED INPUT DATA

H = 0
YES
NO

(A) SEE SH.2

$$DR = \frac{OD}{T}$$

$$PSO = \frac{4.47 \times E}{(DR-1)^3}$$

$$PSID = \frac{PSO}{2.0}$$

$$PS = \frac{GAMA \times H}{144}$$

$$PSU = PS \times 1.5$$

$$PPSU = PS \times 0.8$$

$$CW = 1 - \frac{HW}{3H}$$

$$PB = PS \times CW$$

$$PBU = PB \times 1.5$$

IF $OD < 2.67H \times 12$

$$PWH = \frac{0.48P\left(\frac{OD-T}{12}\right)^2\left[\frac{2.67\,H}{\left(\frac{OD-T}{12}\right)} - 0.5\right]}{2.67\,H^3\,(OD-T) \times 12}$$

IF $OD \geq 2.67H \times 12$

$$PWH = \frac{0.64P}{H\,(OD-T) \times 12}$$

$$TIF = \frac{PWH}{(PWH + PS)}$$

$$PW = PWH\,(1 + TIF)$$

$$TIFF = 1 + TIF$$

$$PWU = PW \times 1.8$$

$$PG = 0.43 \times HW$$

$$PGU = PG \times 1.0$$

$$PVU = PV \times 1.2$$

$$PFU = PF \times 2.0$$

$$DELTAS = \left[\frac{KB \times PS \times DLF}{(0.149PSO + 0.061\ EPRM)}\right] \times 100$$

$$DELTAW = \left[\frac{KB \times PW}{(0.149PSO + 0.061 \times 0.5 \times EPRM)}\right] \times 100$$

INSTALLATION DEFLECTION - DELTAI
SELECT FROM TABLE

(B) SEE SH.2

[1] NOTE: IF H=0 (NONBURIED PIPE) GAMA,P,EPRM,KB = 0

FLOW CHART

PVC PIPE DESIGN PROGRAM FOR DEFLECTION AND STRAIN

FROM SH.1 (A)

$DR = \frac{OD}{T}$

$PSO = \frac{4.47 \times E}{(DR-1)^3}$

$PSIO = \frac{PSO}{2.0}$

$PS = 0$

$PSU = 0$

$PPSU = 0$

$CW = 0$

$PB = 0$

$PBU = 0$

$PWH = 0$

$TIF = 0$

$PW = 0$

$TIFF = 0$

$PG = \frac{62.4 \times HW}{144}$

$PGU = PG \times 1.0$

$PVU = PV \times 1.2$

$PFU = PF \times 2.0$

INSTALLATION DEFLECTION - DELTAI

$DELTAS = 0$

$DELTAW = 0$

$DELTAT = DELTAI$

$EBSU = 0$

$EBWU = 0$

$EBIU = 2.14 \frac{2T}{OD-T} (MF) (DELTAI) \times 1.0$

$EBU = EBSU + EBWU + EBIU$

$ETU = \left[\frac{PFU \frac{(OD-2T)}{2}}{T \times E} \right] \times 100$

$ECSU = 0$

$ECWU = 0$

$EPCWU = 0$

$ECVU = \frac{\left(\frac{OD-2T}{2}\right)}{T \times E} \times PVU \times 100$

$ECU = EC \times 0.8$

$ERU = ER \times 0.8$

$EEWU = \frac{\left(PGU \times \frac{OD}{2}\right)}{T \times E}$

$RA = \frac{EBU}{ERU} + \frac{ECSU + ECWU + ECVU + EEWU}{ECU}$

$RB = \frac{PPF \times EBU}{ERU} - \frac{EPCSU + EPCWU}{ECU}$

$RF = 0$

$RC = \frac{EBU}{ERU} \times RF + \frac{ETU}{ECU} - \frac{EPCSU + EPCWU + ECVU + EEWU}{ECU}$

$JUNK = 0$

$BPRM = 0$

$PCR = 0$

$RD = 0$

$CA = 2$

$PPCR = 0.5 \times CA \times PSIO \times \phi' \times \phi''$

$RE = \frac{(PGU + PVU)}{PPCR}$

NOTE: $\phi' = 0.5$, $\phi'' = 0.75$

(C) SEE SH.3

FROM SH.1 (B)

TOTAL DEFLECTION-DELTAT = DELTAS + DELTAW + DELTAI
{SHORT TERM 3% >Δ
{LONG TERM 5% >Δ

$DELTAT = DELTAS + DELTAW + DELTAI$

$EBSU = 2.50\left(\frac{2T}{OD-T}\right) (MF) (DELTAS) \times 1.5$

$EBWU = 2.50\left(\frac{2T}{OD-T}\right) (MF) (DELTAW) \times 1.8$

$EBIU = 2.14\left(\frac{2T}{OD-T}\right) (MF) (DELTAI) \times 1.0$

$EBU = EBSU + EBWU + EBIU$

$ETU = \left[\frac{PFU \frac{(OD-2T)}{2}}{T \times E} \right] \times 100$

$ECSU = \frac{\frac{OD}{2}}{T \times E} \times PSU \times 100$

$EPCSU = \frac{\frac{OD}{2}}{T \times E} \times PPSU \times 100$

$ECWU = \frac{\frac{OD}{2}}{T \times E} \times PWU \times 100$

$EPCWU = \frac{\frac{OD}{2}}{T \times E} \times PPWU \times 100$

$ECVU = \frac{\left(\frac{OD-2T}{2}\right)}{T \times E} \times PVU \times 100$

$ECU = EC \times 0.8$

$ERU = ER \times 0.8$

$EEWU = \frac{\left(PGU \times \frac{OD}{2}\right)}{T \times E}$

$RA = \frac{EBU}{ERU} + \frac{ECSU + ECWU + ECVU + EEWU}{ECU}$

$RB = \frac{PPF \times EBU}{ERU} - \frac{EPCSU + EPCWU}{ECU}$

$RF = \left[1 + \frac{2\ PF \times \frac{OD - T \times 2}{2}}{(PS + PW)\frac{OD}{2}} \times \frac{DELTAT}{100} \right]^{-1}$

$RC = \frac{EBU}{ERU} \times RF + \frac{ETU}{ECU} - \frac{EPCSU + EPCWU + ECVU + EEWU}{ECU}$

$JUNK = \left(\frac{H}{OD}\right) \times 12 \rightarrow \left(\frac{H}{2R_e}\right)$

$0 < JUNK < 5 \quad BPRM = 0.015 + 0.041 \times JUNK$

$5 < JUNK < 80 \quad BPRM = 0.15 + 0.014 \times JUNK$

$PCR = 0.77 \left[\left(\frac{\left(1 - \frac{DELTAT}{100}\right)^3}{\left(1 + \frac{DELTAT}{100}\right)^2} \right) (CW)(BPRM)(EPRM)(\phi')(PSID)(\phi'') \right]^{1/2}$

$RD = \frac{(PBU + PGU + PVU + PWU)}{PCR}$

$CA = 3$

$PPCR = 0.5 \times CA \times PSIO \times \phi' \times \phi''$

$RE = \frac{(PGU + PVU)}{PPCR}$

NOTE: $\phi' = 0.5$, $\phi'' = 0.75$

(C) SEE SH.3

FLOW CHART

PVC PIPE DESIGN PROGRAM FOR DEFLECTION AND STRAIN

FROM SH. 2

(C)

*** OUTPUT TO SCREEN ***

PIPE TYPE | PIPE CLASS | CELL CLASS | SIZE

THE DIMENSION RATIO OR STANDARD DIMENSION RATIO DR

PIPE STIFFNESS PS AND PSIO

SOIL LOADS PS PSU PPSU

WHEEL LOADS PW PWU PPWU

CW - REDUCTION OF EARTH LOAD FOR BUOYANCY

PB - PRESSURE ON BOTTOM REGION, EARTH LOAD REDUCED FOR BUOYANCY

PBU - ULTIMATE FACTORED PRESSURE OF THE PIPE BOTTOM IN PSI

PWH - PRESSURE DUE TO WHEEL LOADING INCLUDING LOAD FACTORS IN PSI

TIFF - IMPACT FACTOR

PF - INTERNAL PRESSURE IN PSI

PFU - ULTIMATE FACTORED INTERNAL PRESSURE IN PSI

PG - HYDROSTATIC PRESSURE DUE TO GROUND WATER

PGU - ULTIMATE FACTORED GROUNDWATER PRESSURE IN PSI

PV - VACUUM PRESSURE IN PSI

PVU - ULTIMATE FACTORED VACUUM PRESSURE IN PSI

DELTAS - AVERAGE DEFLECTION DUE TO SOIL PRESSURE IN PERCENT

DELTAW - AVERAGE DEFLECTION DUE TO WHEEL LOADING IN PERCENT

DELTAI - DEFLECTION THAT OCCURS DURING INSTALLATION IN PERCENT

DELTAT - TOTAL DEFLECTION IN PERCENT

EBSU - FACTORED RING BENDING STRAIN DUE TO TO SOIL LOADS

EBWU - FACTORED RING BENDING STRAIN DUE TO WHEEL LOADS

EBIU - MINIMUM FACTORED RING BENDING STRAIN THAT OCCURS DURING INSTALATION

EBU - SUM OF FACTORED BENDING STRAINS

ETU - MAXIMUM RING TENSILE STRAIN DUE TO INTERNAL PRESSURE IN PIPE

EEWU - STRAIN DUE TO EXTERNAL WATER LOAD

EPCWU - MINIMUM FACTORED RING COMPRESSION STRAIN DUE TO THE WHEEL LOADING

ECSU - MAXIMUM FACTORED RING COMPRESSION STRAIN DUE TO EARTH LOADS

EPCSU - MINIMUM FACTORED RING COMPRESSION STRAIN DUE TO THE SOIL LOADS

ECWU - MAXIMUM FACTORED RING COMPRESSION STRAIN DUE TO WHEEL LOADS

ECVU - FACTORED RING COMPRESSION STRAIN DUE TO VACUUM

RA - INDEX OF STRENGTH ADEQUACY FOR COMPRESSION STRAIN

RF - REROUNDING FACTOR FOR PRESSURIZED PIPE

RC - INDEX OF STRENGTH ADEQUACY FOR TENSION IN PRESSURE PIPE

RB - INDEX OF STRENGTH ADEQUACY FOR TENSION STRAIN (MOST OFTEN CRITICAL FOR PERFORATED PIPE)

PCR - CRITICAL BUCKLING PRESSURE OF PIPE IN PSI

RD - INDEX OF BUCKLING STRENGTH ADEQUACY BASED UPON MODIFIED AWWA FORMULA

PPCR - CRITICAL BUCKLING PRESSURE ON PIPE UNDER HYDROSTATIC LOADING

RE - INDEXOF BUCKLING STRENGTH ADEQUACY BASED ON HYDROSTATIC BUCKLING LOADS

JUNK - INTERMEDATE STEP USED IF HAND CALCULATIONS ARE DONE IN BUCKLING COMPUTATION

BPRM - INTERMEDATE STEP USE IF HAND CALCULATIONS ARE DONE IN BUCKLING COMPUTATION

*** MENU ***

1. CHANGE INPUT DATA
2. PRINT LOCAL
3. CREATE A PRINT FILE
4. RETURN TO MAIN MENU
5. MAKE STRAIN COMPS BY DEGREES OUTPUT TO SCREEN
6. MAKE STRAIN COMPS BY DEGREES OUTPUT TO PRINTER

(5)

(2)

PRINTED OUTPUT

INPUT DATA

ASTM D-1785 IPS SCH40 12454-B
6 INCH DIAMETER PERFORATED PIPE

FILL HEIGHT IN FEET	33
PIPE OD IN INCHES	6.625
SOIL UNIT WEIGHT IN PCF	123
WHEEL LOAD IN POUNDS	10000
SOIL MODULUS E' IN PSI	2000
PIPE WALL THICKNESS IN INCHES	.28
YOUNGS E FOR PVC PIPE IN PSI	400000
INTERNAL PRESSURE	1
BEDDING FACTOR	.1
STRENGTH IN CREEP EC	1
STRENGTH IN RELAXATION ER	3
WATER HEIGHT IN FEET	1
PERFORATION FACTOR	2.3
VACUUM IN LINE	1
MOMENT FACTOR	.75
DEFLECTION LAG FACTOR	1.5

OUTPUT DATA

ASTM D-1785 IPS SCH40 12454-B 6

DR OR SDR	23.66072
IMPACT FACTOR FOR LIVE LOAD	1.001
SOIL DELTA	2.918%
WHEEL DELTA	0.004%
INSTALLATION DELTA	2.000%
TOTAL DELTA	4.922%

IF RA,RB,RC,RD, OR RE IS GREATER THAN 1 THEN REDESIGN

IF ONLY RB > 1 CAN USE STEP 5 OF MENU FOR HOLE LOCATIONS FOR RB

RA COMP. STRAIN INDEX	0.5809
RB TENSION STRAIN INDEX	0.8832
RC TENSION INDEX	0.3423
RD BUCKLING INDEX	0.2969
RE HYDRO. BUCKLING INDEX	0.0377

FOR TH, 0° - 90°

YES / NO

$$TH = TH1 \times \frac{3.1415927}{180}$$

$$COEFF = -0.25 + 0.5 \times \cos(TH)^2$$

$$COEFF = |COEFF|$$

$$DEG = TH1$$

$$AEBU = \frac{20 \times DELTAS \times (T) \times COEFF}{(OD-T)} (MF)\ 1.5 + \frac{20 \times DELTAW \times (T) \times COEFF}{(OD-T)} (MF)\ 1.8 + \frac{(17.12)\ DELTAI \times (T) \times COEFF}{(OD-T)} (MF)\ 1.0$$

$$ARB = \frac{PPF \times AEBU}{ERU} - \frac{EPCSU + EPCWU}{ECU}$$

IF ARB < 1

YES / NO

TH1 = TH1 + 1

PRINT DEG & ARB